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Classification of Shoulder Complaints in General Practice by Means of Nonmetric Multidimensional Scaling

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ABSTRACT. Groenier KH, Winters JC, Meyboom de Jong B. Classification of shoulder complaints in general practice by means of nonmetric multidimensional scaling. Arch Phys Med Rehabil 2003;84:812-7.

Objectives: To determine if a classification of shoulder complaints in general practice can be made from variables of medical history and physical examination with nonmetric multidimensional scaling and to investigate the reproducibility of results from an earlier hierarchical cluster analysis.

Design: A classification study performed using nonmetric multidimensional scaling.

Setting: Four general practices in the Netherlands.

Participants: Ninety-eight consecutive patients presenting with shoulder complaints in general practice were examined at study entry and after 2 weeks of treatment.

Intervention: All patients were treated with a nonsteroidal anti-inflammatory drug during the first 2 weeks of treatment.

Main Outcome Measures: Eleven variables of the medical history and 19 variables of the physical examination were used in a nonmetric multidimensional scaling analysis.

Results: The analysis of the data at inclusion as well after 2 weeks shows that a 1-dimensional configuration can be used to represent the shoulder complaints. The results of the cluster analysis are consistent with the results of the nonmetric multidimensional scaling. The degree of limitation in range of motion and the degree of pain felt by the patients together determine the position of the patients on the dimension.

Conclusions: The analysis shows that detailed classifications for the diagnosis of patients with shoulder complaints in general practice cannot be confirmed by empirical data available to the general practitioner. The results confirmed the recommendations of the new Dutch Guidelines for Shoulder Complaints, issued in 1999.

Key Words: Classification; Cluster analysis; Diagnosis; Family practice; Rehabilitation; Shoulder pain.

DIAGNOSIS IN PATIENTS with shoulder complaints is a complex problem.[1] Various classifications are used for the physical examination, the diagnostic interpretation, and the treatment of shoulder complaints.[2-10] However, there is very little agreement among these classifications regarding diagnostic criteria or the existence of specific lesions. The number of categories distinguished varies from 4[3] to 8.[6] All classification systems are developed from pathologic anatomic disorders. The authors describe to some extent what limitations in the movement of the shoulder can be expected given a certain disorder and the nature of the pain as experienced by the patient. The well-known classification by Cyriax[10] describes in great detail how a lesion of a specific structure is diagnosed by a structured physical examination of the shoulder. Nevertheless, empirical research concerning the validity of the various classification systems is lacking. There are only a few studies in which the agreement among doctors or physiotherapists is assessed regarding the diagnostic classification of shoulder disorders.[11-15] Of them, all studies but one[11] show a clear lack of interobserver agreement.

In the Netherlands, de Jongh[16] tried to construct a classification based on variables of medical history and physical examination with the aid of hierarchical cluster analysis. The results of de Jongh[16] show that 2 main groups prevail, namely, a group with limitations in the range of motion (ROM) of the glenohumeral joint and a group with a painful abduction motion. Both main groups are divided into 2 and 3 subgroups, respectively.

Winters et al[17] replicated the de Jongh study and found 3 groups of patients—1 group with very few limitations on the movement, 1 group with moderate limitations of the movement, and a small group of patients with very serious limitations in the ROM. Both studies came to the conclusion that distinct groups of patients can by found, but that the distinction between the groups in no way mirrors the classifications described earlier in the literature.

It is, however, conceivable that this conclusion was, at least partly, based on the technique used. Results of hierarchical cluster analysis are highly influenced by how the similarities or dissimilarities between patients are measured and which specific method of cluster analysis is chosen. Furthermore, patients are divided into distinct nonoverlapping groups. Perhaps patients can be characterized by 1 or more dimensions that reflect the absence or presence of certain lesions.

In this study, we attempted to characterize patients with shoulder complaints in a way that might circumvent the limitations of hierarchical cluster analysis by using nonmetric multidimensional scaling.

The questions that we tried to answer in this study were: (1) Can patients who present shoulder complaints in general practice be characterized, based on data from medical history and physical examination, in a way that reflects earlier described categories? (2) Which items from medical history and physical examination define the characterization? (3) What is the relation between the results of earlier hierarchical cluster analysis and the results of nonmetric multidimensional scaling? and (4) Is the categorization of patients stable over time?

METHODS

Participants

All patients with shoulder complaints (duration, <27wk) seeking consultation in 4 general practices in Groningen, The

From the Department of General Practice, University of Groningen, Groningen, The Netherlands.

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Netherlands, between January 1 and June 1, 1993, were included in the study.[18]

Shoulder complaints were defined as pain localized in the region of the deltoid muscle, the acromioclavicular (AC) joint, the superior part of the trapezoid muscle, and the scapula, with or without limitation in the ROM of the upper arm and/or the shoulder girdle. The pain could be present with or without radiation in the arm.

Patients with the following conditions were excluded from the study: (1) treatment for shoulder complaints in the 6 months before consultation, (2) bilateral shoulder complaints, (3) the presence of specific rheumatic disorders, (4) shoulder complaints because of acute severe trauma (patients with a history of a shoulder sprain were not excluded), (5) presence of cervical disk herniation, (6) extrinsic shoulder complaints resulting from of internal disease, (7) presence of dementia or other psychiatric disorders, and (8) refusal to participate in the study.

Patients were categorized into 1 of the following 3 groups: (1) synovial disorder: disorders of the synovial cavity of the scapulohumeral joint, the subacromial cavity, and/or the AC joint; (2) shoulder girdle disorder: no disorders in the synovial structures, but functional disorders in the shoulder girdle (the shoulder girdle consists of the cervical spine, upper thoracic spine, and/or upper ribs); and (3) combination diagnosis: a combination of shoulder girdle and synovial disorder.

Variables

History taking. During the history taking, demographic characteristics (age, gender) and clinical characteristics, such as the duration of the shoulder complaints, a history of shoulder problems, the presence or absence of a shoulder sprain, and a feeling of numbness or tingling, were recorded.

Pain measurement. Patients were asked to indicate the extent of the pain on a 6-item questionnaire. The 6 questions—pain at rest, pain during motion, pain during the night, sleeping problems due to pain, inability to lie on the affected side, and presence of radiated pain—were scored on a 4-point scale. The patients were also asked to indicate the severity of their overall pain on a 101-point numeric pain scale, which was converted to a 4-point scale. From the 7 items (6 for pain, 1 for severity), a sum score indicating the amount of shoulder pain was computed, ranging from 7 points (no pain at all) to 28 points (severe pain).[19] In the analysis, the most discriminating items of the questionnaire (overall pain, pain at night, pain at motion) were used. Furthermore another item from history taking, pain at exertion, was used because of its discriminating power.[19]

Also, the presence or absence of pain in the C4 and/or C5 dermatome was noted.

Physical examination. The physical examination consisted of inspection and recording of the degree of limitation (in increments of 10°) of the active and passive ROM compared with the unaffected side. Interruption of the scapulothoracal rhythm; the presence or absence of pain around 90° of abduction or anywhere in the abduction, at the end of the horizontal adduction, or at the end of abduction; and the degree of resistance felt at the end of the lateral rotation were recorded. The muscle tendons on the head of the humerus and of the AC joint were also palpated. Limitation in the motion of the cervical spine and pain with motion of the cervical spine was recorded.

All variables used in the analysis and their level of measurement are shown in table 1.

The physical examination and pain measurement were done at the beginning of the study, by the 4 participating general practitioners, and after 2 weeks of treatment with a nonsteroidal anti-inflammatory drug (NSAID), by the 2 principal investigators, none of whom were informed about the diagnosis at study commencement.

Table 1: Variables Used in the Analysis and Their Level of Measurement

	Level of Measurement
Variables from medical history	
Overall pain	4-point scale
Pain during the night	4-point scale
Pain at motion	4-point scale
Pain with exertion	4-point scale
Pain in C4 dermatome	Dichotomous
Pain C5 dermatome	Dichotomous
Feeling of tingling	Dichotomous
Feeling of numbness	Dichotomous
Duration of the pain	In weeks
Earlier shoulder complaints	Dichotomous
Distortion in anamnesis	Dichotomous
Variables from physical examination	
Limitation of motion of the cervical spine	4-point scale
Pain at motion of the cervical spine	Dichotomous
Pain when pressuring the tendon of the musculus supraspinatus	Dichotomous
Pain when pressuring the AC joint	Dichotomous
Interruption of the scapulothoracal rhythm	Dichotomous
Pain around 90° of abduction	4-point scale
Pain anywhere in the abduction	4-point scale
Limitation of the active abduction	Continuous
Limitation of the active anteflection	Continuous
Limitation of the active lateral rotation	Continuous
Limitation of the active medial rotation	Continuous
Limitation of the passive abduction	Continuous
Limitation of the passive abduction with fixation of the scapula	Continuous
Limitation of the passive lateral rotation	Continuous
Limitation of the passive medial rotation	Continuous
Limitation of the passive horizontal adduction	Continuous
Degree of resistance felt at the end of the lateral rotation	Dichotomous
Pain at the end of the horizontal adduction	Dichotomous
Pain at the end of the abduction	Dichotomous

Statistical analysis. The dissimilarities among patients were calculated from medical history variables, physical examination variables, and pain measurements. All variables were standardized on a mean of 0 and a standard deviation (SD) of 1 because they were measured on different scales. The squared Euclidian distance was chosen as the measure of dissimilarity.

Nonmetric multidimensional scaling refers to a class of statistical techniques that transforms a matrix of dissimilarities into a geometric configuration or map of points in *n*-dimensional space.[20] Each patient is represented by a point in this space in such a way that the order of distances between the points reflects the order of the computed dissimilarities as close as possible. This is accomplished by a process of iteration for a given number of dimensions.[21] The difference between the order of the distances and the order of the dissimilarities is

Table 2: Patient Characteristics at Inclusion Categorized by Diagnosis Groups

	Shoulder Girdle (n=22)	Synovial (n=58)	Combinations (n=21)	Total (n=101)
Percentage female (n)	63.6 (14)	58.6 (34)	52.4 (11)	58.4 (59)
Mean age ± SD (y)	42.8±12.8	51.9±15.5	44.1±15.3	47.3±15.4
Median duration (wk) of complaints (1st quartile, 3rd quartile)	6.0 (1.8,27.0)	5.0 (2.0,21.0)	3.0 (1.0,11.0)	4.0 (1.0,26.5)
Mean total pain score ± SD	17.1±4.5	19.3±5.2	19.4±4.5	18.8±5.0

expressed in a measure called *stress.*[22] A lower stress value indicates a better fit between the distances and the dissimilarities. Usually a larger number of dimensions will lead to a lower value of stress. The aim of the method is to find a configuration with a low dimensionality and, simultaneously, an acceptable level of stress.

A common method for finding the optimal number of dimensions is to plot the stress values against the number of dimensions. If the resulting curve shows an "elbow," then it is at that point that the optimal number of dimensions is found. Beyond that point the number of dimensions increases, but the stress value hardly decreases.

However, Spence and Ogilvie[23] showed that the stress value is determined not only by the fit of the configuration but also by the number of points in the configuration. Stress values will be larger with an increasing number of points. Furthermore, they showed that if the data are not perfectly accurate (ie, they contain a certain amount of "noise"), the curve of the stress values tends to "flatten out," thus making it difficult to detect what the optimal number of dimensions should be.[23]

Spence and Graef[24] suggested an alternative way to determine the optimal number of dimensions by means of simulation. A configuration with a known dimensionality is generated containing the same number of points as the empirical data. A random component is added to the distances between the points of the configuration. The SD of the random component (relative to the SD of the distances) represents the level of noise in the configuration. Then this simulated configuration is subjected to nonmetric multidimensional scaling in a number of dimensions, say 1 to 6. The resulting stress values are plotted against the number of dimensions. This process is repeated for various configurations and various levels of noise. By comparing the stress curve of the empirical data with the curves of the simulated data, one can find the optimal number of dimensions. The simulated curve that most closely matches the empirical curve corresponds with the optimal configuration. The method not only enables the researcher to determine the optimal number of dimensions but also indicates the amount of noise that is present in the empirical data.

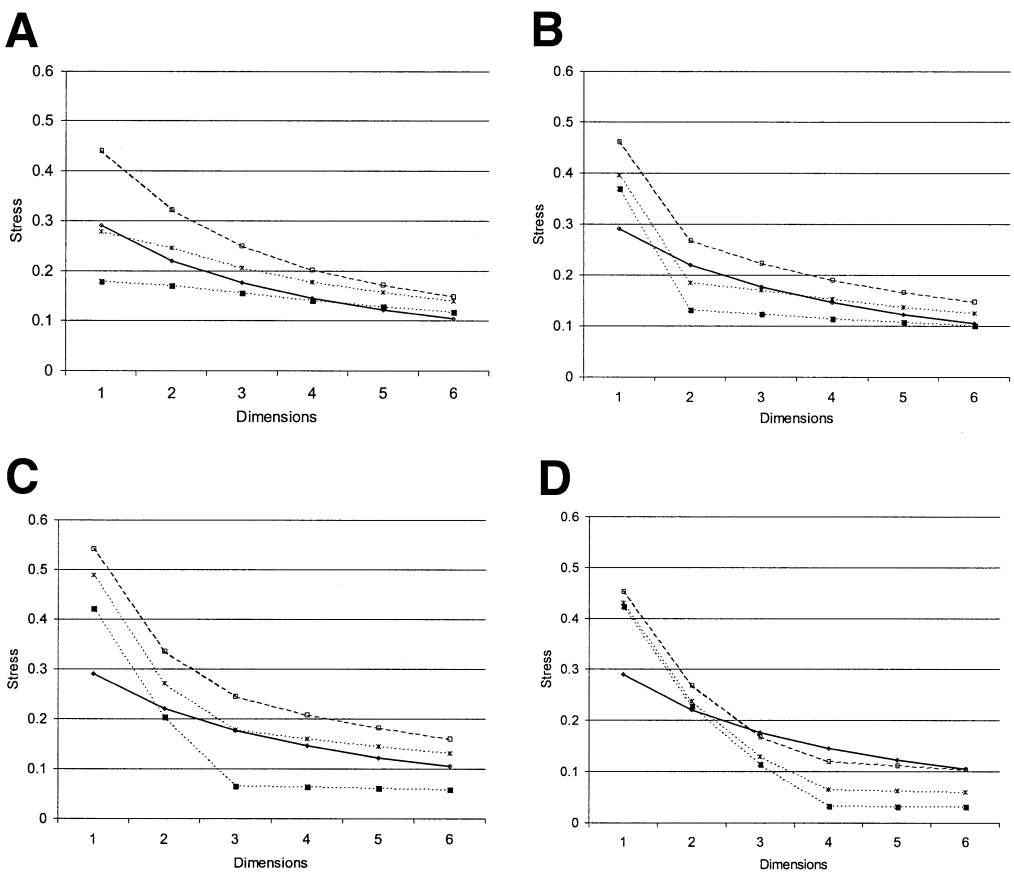

Fig 1. Stress curves for known configurations in 1 to 4 dimensions with various levels of noise compared with the stress curve of the present study. (A) Configuration in 1 dimension with 10% noise (■), 23% noise (×), 56% noise (□), and our study (◇); (B) configuration in 2 dimensions with 9% noise (■), 18% noise (×), 40% noise (□), and our study (◇); (C) configuration in 3 dimensions with 3% noise (■), 23% noise (×), 48% noise (□), and our study (◇); and (D) configuration in 4 dimension with 1% noise (■), 4% noise (×), 14% noise (□), and our study (◇).

In our study, we used the method of Spence and Graef[24] to determine the optimal configuration. The relationship between the original variables and the resulting dimensions was investigated by means of Pearson correlation coefficients. The results of the nonmetric multidimensional scaling were compared with the results of an earlier published hierarchical cluster analysis.[17] The significance of the differences between the scores of the patients on the dimensions for the clusters found were tested by using the Kruskal-Wallis test. A P value less than .05 was regarded as statistically significant.

The relationship between the results of the nonmetric multidimensional scaling from the data at inclusion were compared with the results found after 2 weeks of therapy by means of Spearman correlation coefficients.

RESULTS

At Inclusion

Originally, 101 patients were included in the investigation. More than half (58.4%) of the patients were women. Mean age ± SD was 47.3±15.4 years. Shoulder problems originating from the shoulder girdle was diagnosed in 22 patients, synovial complaints were found in 58 patients, and in 21 patients combinations were diagnosed. Table 2 shows the patient characteristics for each diagnostic group.

Three patients had missing data at inclusion, so the analyses were done with the data of 98 patients. Figures 1A to 1D show the resulting stress curves of the simulated configurations with 98 points in 1 to 4 dimensions and varying levels of noise. A nonmetric multidimensional scaling was done for each configuration in 1 to 6 dimensions. The resulting stress value for each solution is plotted against the number of dimensions. Also, the stress curve for the empirical data is shown in each figure. From the figures one can see that the curve of the empirical data best fits the curve for the simulated configuration in 1 dimension (fig 1A) with a noise level of 23%. So the dissimilarities of the patients can be mapped in a 1-dimensional space. The scores on this dimension are standardized on a mean of 0, so a positive score indicates more serious complaints, whereas a negative score indicates less serious complaints. The stress curves also show that, in configurations with more than 1 dimension, the "traditional" elbow in the curves disappears when the amount of noise increases.

In table 3, the results of the correlation analysis are shown for the variables from medical history and those from physical examination. The variables in the table are ordered according to the size of their correlation coefficient with the score on the dimension at study commencement. The variables from the physical examination have the highest correlation with the dimension followed by the variables that indicate how much pain the patient experienced. Less influential are variables like feelings of tingling or the presence of a distortion in history taking. The relationship between the 1-dimensional solution of the nonmetric multidimensional scaling and the hierarchical cluster analysis performed by Winters et al[17] is investigated by plotting the scores of the patients on the dimension for each cluster found by Winters,[17] patients with little pain or few limitations in the ROM (cluster 1), patients with moderate pain or limitations in ROM (cluster 2), and patients with acute pain and severe limitations in the ROM (cluster 3). Figure 2 shows that patients in the 3 clusters have significantly different scores on the dimension (Kruskal-Wallis test, $P<.0005$), although some overlap exists between the scores of clusters 1 and 2.

Table 3: Correlation Coefficients Between the Score on Dimension 1 and Variables From Medical History and Physical Examination at Inclusion and After 2 Weeks of Therapy

	Correlations	
	At Inclusion	After 2wk of Therapy
Variables from medical history		
Pain at motion	**.546**	.203
Pain during the night	**.465**	.222
Pain with exertion	**.424**	.064
Overall pain	**.316**	**.344**
Pain in C5 dermatome	.194	.189
Earlier shoulder complaints	.059	−.076
Distortion in anamnesis	−.023	−.116
Feeling of tingling	−.040	.058
Pain in C4 dermatome	−.070	.142
Feeling of numbness	−.160	.165
Duration of the pain	−.241	.134
Variables from physical examination		
Limitation of the passive lateral rotation	**.796**	**.385**
Limitation of the active lateral rotation	**.793**	**.575**
Limitation of the passive abduction	**.775**	**.563**
Limitation of the active anteflection	**.772**	**.443**
Limitation of the active abduction	.715	**.563**
Limitation of the passive abduction with fixation scapula	**.693**	**.304**
Pain anywhere in the abduction	**.563**	**.448**
Limitation of the passive medial rotation	**.507**	**.655**
Limitation of the active medial rotation	**.496**	**.517**
Pain at the end of the abduction	**.442**	**.341**
Interruption of the scapulothoracal rhythm	**.373**	**.403**
Resistance felt at the end of lateral rotation	**.358**	**.316**
Limitation of the passive horizontal adduction	**.329**	**.730**
Pain pressuring tendon of supraspinatus	**.305**	.074
Pain at the end of horizontal adduction	.160	**.435**
Pain pressuring the AC joint	.144	.186
Pain around 90° of abduction	−.017	−.012
Pain at motion of the cervical spine	−.136	.181
Limitation of motion of the cervical spine	−.153	**.318**

NOTE. Coefficients >.300 are in bold face.

After 2 Weeks of Therapy

The stress curve for the nonmetric multidimensional scaling solution of the data collected 2 weeks after the start of therapy is shown in figure 3, together with the curve resulting from the data collected at inclusion. The curves coincide almost perfectly with each other. Therefore, for the data collected after 2 weeks, a 1-dimensional representation also is the optimal solution.

The results of the correlation analysis are shown in table 3. As with the analysis at inclusion of the patients in the study, the variables from physical examination have the highest correlation with the score on the dimension. However, most correlation coefficients were somewhat lower.

The relationship between the patients' score on the resulting dimension with the results of the hierarchical cluster analysis from the study of Winters[17] is shown in figure 4. The scores on

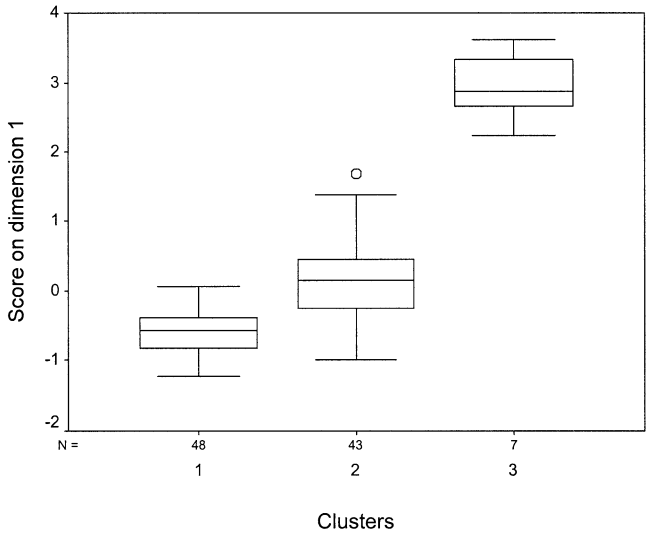

Fig 2. Distribution of scores for 3 clusters on dimension 1 at inclusion ($P<.0005$).

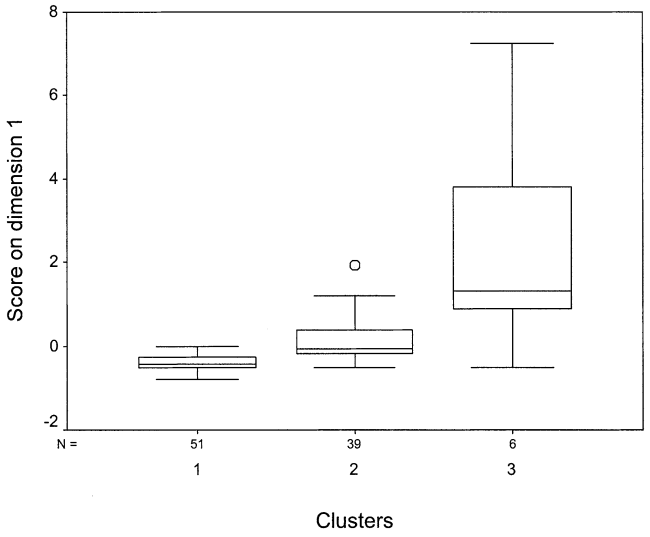

Fig 4. Distribution of scores for 3 clusters on dimension 1 after 2 weeks ($P<.0005$).

the dimension are plotted for each cluster (cluster 1, hardly any limitations; cluster 2, moderate limitations; cluster 3, severe and acute limitations). There was a highly significant difference among the 3 clusters (Kruskal-Wallis test, $P<.0005$), but there was more overlap between the score distributions than at inclusion.

The relationship between the results of the analysis at inclusion and those after 2 weeks can be seen in the scatterplot of figure 5. The Spearman correlation coefficient was .511. Although the scores on the dimension after 2 weeks generally were lower than those at inclusion, there still were patients who scored high after 2 weeks of therapy.

DISCUSSION

The most striking result of this study is the fact that the structure of shoulder complaints as presented to the general practitioner was even more simple than was concluded by de Jongh[16] and Winters et al.[17] Patients can be ordered according to the degree of limitation in ROM and the amount of pain they experience on a single dimension. From the variables of the medical history and the physical examination, it was only possible to conclude how the patients were limited in their movements and how much pain they experienced during the movements. The low correlation of the variables' distortion, earlier shoulder complaints, feeling of numbness and tingling, and pain in the C4 or C5 dermatome can be explained from the low incidence of these variables.

After 2 weeks of treatment with an NSAID (during which the pain and the limitation in ROM subside), a further differentiation in diagnoses was not possible. The structure of the shoulder complaints remained the same. However, the correlation coefficients of the variables from history taking and physical examination with the dimension were somewhat

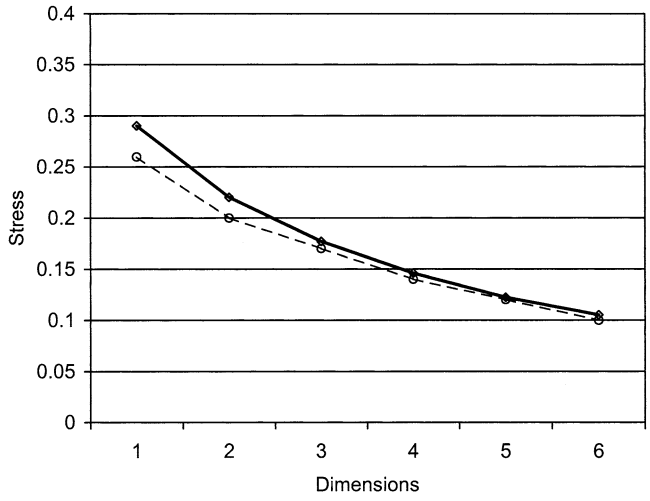

Fig 3. Stress curves at inclusion (◇) and after 2-week treatment with an NSAID (○).

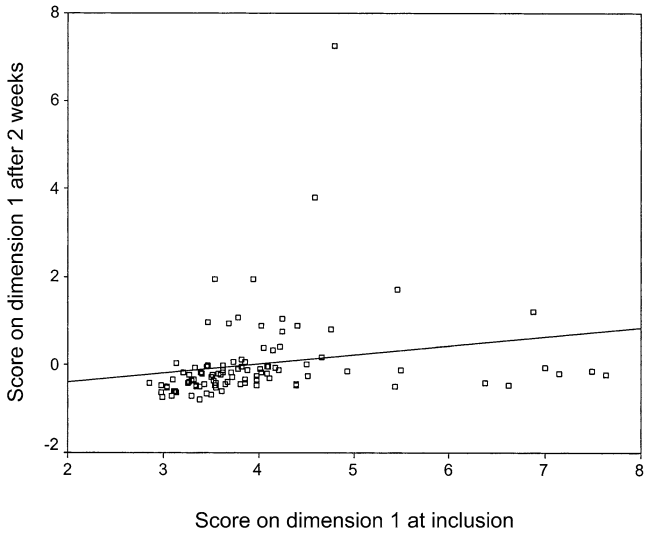

Fig 5. Relationship between the score on dimension 1 at inclusion and the score on dimension 1 after 2 weeks (Spearman ρ=.511).

lower. After 2 weeks of treatment, the severity of the complaints diminished, resulting in less variation in the scores. Therefore, all correlation coefficients were lower because of restriction of range.[25]

The 3 clusters that were found by Winters et al[17] are merely an expression of the severity of the complaints. Differentiating between complaints originating from the shoulder girdle and the glenohumeral joint cannot be made with the aid of the variables used in this study.

Earlier, Sobel et al[18,19] showed that general practitioners could not classify patients according to the criteria laid out by Cyriax.[9,10] Also, from the studies of de Winter,[14] Liesdek et al,[12] and Bamji et al,[13] it becomes clear that the reproducibility of the physical examination is lacking. Their results agree with the amount of noise (from the stress value) that is present in our data.

The results of our study support the recommendations of the new National Guidelines for Shoulder Complaints of the Dutch College of General Practitioners, issued in 1999. In these guidelines, only the amount of pain the patient experiences and the amount of limitation in the movement of the shoulder joint are used to classify patients in 2 groups: those with pain with limitations in ROM and those with pain without limitations in ROM.

CONCLUSION

Even if the structure of shoulder complaints is 1-dimensional, this does not mean that finding meaningful clusters of patients with common characteristics will not be possible. There were highly significant, different scores among the 3 clusters. At inclusion to the study, the scores of the third cluster did not overlap with the scores of the other clusters. However, a differentiation of patients will only be meaningful when this has consequences for the choice of treatment and its results. Further research on the classification of patients with shoulder complaints is needed to answer this question.

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